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AGRICULTURAL SCIENCE—ITS HISTORY AND RECENT DEVELOPMENT[1]

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I propose to deal with the subject in the nature of a general address for two reasons. Firstly, your Secretary's request for a lecture by me, reached me just before I left on tour, leaving me very little time for adequate preparation. I should have liked to deliver a considered scientific lecture, but, that meant equipping myself with diagrams, statements, slides, and all those paraphernalia which one scientist would like to have, when addressing fellow-scientists. On thinking over, I thought it would not be a bad plan to give, instead of a formal scientific address, a general talk. It is a great advantage for research workers to take from time to time, a broader and a more general outlook by reading the history of agriculture and agricultural science. In fact, I would suggest to some of the younger members of the Association that they should take up the subject as a hobby, and I can assure them it will be of absorbing interest. In this country, with its long civilization, you will find the history of agriculture and agricultural practices is a unique subject that will more than repay the attention you devote to its study.

The history of agricultural science is very short; it is hardly a century old. Most of the agricultural practices had developed before agricultural science even began. Compared with Engineering, for example, the position is quite the reverse in agricultural science. Electrical Engineering in fact is a child of the laboratory and an application of pure science,—physics, and you have only to conceive of what modern industry would be without Electrical Engineering, to realize this. With agriculture, however, actual knowledge is, and for some time will be, far ahead of the scientific theories and explanations.

Modern agricultural science developed from the days of Liebig and Schubler in Germany, Boussingault in France, and Lawes and Gilbert in England. These latter two worked in Rothamsted, and as most of you are generally familiar with it, I will trace the growth of agricultural science with the history of Rothamsted as a background, giving personal and interesting details of its growth.

Lawes was an English country gentleman, a type that is fast disappearing in these days,—and he succeeded to a small estate at about the time of the end of the Napoleonic wars. He found his estate impoverished and the fertility of his soils low. He recognized that he had to get more money out of his lands somehow. He had been to Oxford, but for some obscure reason returned without a degree. He fitted up a room in his house as a chemical laboratory, and tried various experiments. The only manures generally available and used in those days, were farmyard manure and chalk. He found that liberal doses of farmyard manure and chalk gave bigger

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yields of crops and he set himself to find out why this was so. He started analyzing soils and plants, and began supplying to the soil, the ingredients that it was deficient in.

In this manner, phosphate was the first thing he started with. In those days phosphatic manures were generally used mainly in the form of powdered bones, but the phosphate in them was not very available. Lawes set himself to make this more available by treating bones with sulphuric acid, and tried this treated product in a number of pot-experiments on turnips—a very responsive plant. He had the luck of a successful scientist, for the pot-experiments showed that phosphoric acid had been made available by sulphuric acid. That bones treated like this could increase yield, set him thinking. He was a unique man with a clear, far-reaching, scientific outlook associated with good business sense, a rare combination of two different mental qualities. He realized that it would be to his financial advantage and to that of agriculture if he could start marketing his phosphate product as a fertilizer. The serious trouble was that the supply of bones was not sufficient for the manufacture of 'super'. The only other source in England of phosphates were the deposits found in the various parts of the country, known as *coprolites*, of which only small supplies were available. At this time however, the geologists' discovery of large areas of rock-phosphate in different parts of the world solved the problem and brushed aside difficulties about the source of raw material.

Lawes set up a small factory for the manufacture of 'super' with rock-phosphate obtained from Africa, and sulphuric acid available at home. It is interesting and amusing to read how careful he had to be, because about a hundred years ago it was not considered correct for a gentleman to be engaged in such pursuits, and he had therefore to carry out the manufacture in a somewhat obscure manner. We have in the archives at Rothamsted an original copy of the *Gardener's Chronicle*—a paper of those days,—in which can be found the first advertisemeut that Lawes put in about his new 'super'. It is a small one occupying about half an inch in one column.

In a short time, Lawes' finances improved. But he had more at heart the improvement of agriculture in the whole country and the enhancement of agricultural returns by the application of phosphates in an available form to stimulate yields. He set out a number of plots, to test over a number of seasons, the effect of 'super' and of farmyard manure on the growth of crops. He carried out chemical analysis of the farmyard manure, the soil and the crop, to trace any relationships between each other and to see whether any particular manure could be advantageously applied. Analysis showed that farmyard manure contained several fertilizing ingredients, and later on, he started a series of plots manured with farmyard manure and these chemical compounds. This indeed was the beginning of the famous Broadbalk experiments at Rothamsted, started in 1839 and continued without change up to the present day.

Not being himself a fully trained chemist, he felt the need for the co-operation of one, and he appointed as his private assistant Dr. Gilbert, who had studied in Germany and in University College, London. This was in 1843. Gilbert was a magnificent worker on the detailed side. Lawes could sweep out the broad outlines and Gilbert could fill in the details, and thus started the combination of this fortunate pair. It was at about this time that Liebig working in Germany, set forth his theory of plant-nutrition based on his analyses. He held that the soil consisted essentially of phosphates, potash, and silicates, and supplied these mineral ingredients to plants, which got their nitrogen indirectly from the air. According to him therefore, the only necessary manure was a collection of minerals to be applied to the soil. His theory sounded quite reasonable, and he was so confident of it himself that he patented and put on the markets, compounds to provide potash and phosphorous for soils. Trouble was however, in store for Liebig. His manures failed to produce any increased yield. During one stage of the process of manufacturing these compounds, fusion was employed. This rendered the ingredients unavailable; they were in fact, only potential manures. He was also in error in asserting that nitrogen need not be included in the ingredients to be added to the soils.

Lawes showed by practical experiments that nitrogen was necessary. He laid out a number of plots manured with farmyard manure, Liebig's mineral mixture, the same mixture plus nitrogen in increasing doses and a no-manure control plot, and the results were conclusive. (For supplying nitrogen he used ammonium sulphate which was available as a by-product of the gas industry). The plot manured with the mineral mixtures of Liebig gave yields little better than the no-manure plot; the three plots with mineral mixtures plus increasing doses of nitrogen gave larger yields, and the yield of the last plot—that manured with the largest dose of nitrogen—was equal to the yield of the farmyard manure plot itself.

Lawes thus showed the importance of nitrogen, potash and phosphoric acid as essential elements, recognizing at the same time the importance of temperature, climate, etc., on making these available. Thus the conclusion of Lawes' first agricultural demonstration was practical and obvious. 'Supply the impoverished soils in England with nitrogen, phosphorous and potash.' The results of his experiments were remarkable. In a few years, the yield of wheat per acre in the surrounding areas rose by about 10 bushels or 600 lbs. This is perhaps the greatest single achievement in modern agriculture, and was entirely due to Lawes and Gilbert.

Lawes extended his manure factory and began to manufacture, besides 'super', other manures as well. His finances improved and he soon became a wealthy man. But he devoted himself at the same time to carrying on scientific work. Throughout his life, he kept his scientific and his commercial activities separate from each other. Thus Rothamsted was from its beginning, an independent research station and not a research laboratory attached to a manure manufactory.

They were an ideal pair; Gilbert refusing to move one step forward until he had proved to the hilt the soundness of every hypothesis, and Lawes, eager to push forward with new ideas; the wise, far-seeing man with his broad outlook, and the trained research worker passionately fond of details formed a pair in perfect harmony. They can be compared to a steam-engine; Lawes was the piston, and Gilbert the flange on the wheels.

Their note-books, which are preserved at Rothamsted, give an insight into their natures. Lawes' note-books are neatly kept, but are relatively empty, although the main plan and the background are there. Gilbert's, on the other hand, are almost unintelligible, crowded with figures and calculations. But every figure there, and every calculation was a brick in the edifice he was building. These note-books convey more than anything else, the true characteristics of these two men. It was fortunate that both were endowed with vigorous constitutions and thus they worked together for nearly 60 years—Lawes died in 1900, and Gilbert in 1901—and the length of this partnership is unique in agricultural science, or in any other science for that matter.

Lawes' and Gilbert's studies on artificial manures and yields of crops were only two aspects of their activities. They did other work besides. They devoted attention to the permanent meadow land at Rothamsted and to the improvement of pastures. They tried to find out that indefinable term in agricultural produce—*quality*—as they realized that yield (or quantity) was not the sole criterion; the flours from the wheats of the different plots of Broadbalk field were given to an expert baker, for a proper assessment of their quality and suitability to produce good loaves. They thus tried to trace a relationship between quality and manurial treatment, which only in recent years has come to be fully investigated. They also tried experiments in plant breeding and the differential response of varieties to treatment. They experimented as well on the feeding of animals, as they realized that the kind and quantity of agricultural produce fed to animals, is reflected in the quantity of milk and meat produced. Thus they started nutritional experiments on pigs and cattle, analyzing carcases of animals and accumulating vast stores of detailed information. The modern science of animal nutrition started in fact, from their work.

Thus, the whole gamut of agricultural science, plant-breeding, botany, chemistry, physics, bacteriology and even animal breeding and animal nutrition—was traversed by Lawes and Gilbert. More important than anything else, they had an eye for the future. They knew their methods were not final, and saw the importance of the repetition of their experiments on the same material at some later date. They established therefore, a museum of raw materials—soil samples, wheats, barleys, hays, and even samples used in the animal nutrition experiments. You can see to this day at Rothamsted, soil samples from depths of 9 inches to 9 feet, taken as early as 1843, kept in bottles hermetically sealed. The inestimable value to future workers of such a procedure was perhaps not fully visualized, even by Lawes and Gilbert themselves. To give only one example, when recently there arose a question as to how long amœbæ could remain alive in the cyst form in a dry soil, the problem would have necessitated examining the dry soil at intervals over a very long period. But the foresight of Lawes and Gilbert enabled the answer to be obtained in a few days. For the experiment could be done ' backwards ', as it were, by taking in turn the older samples until one came to a sample in which no amœbæ had survived. The philosophy of their lifework was ' do everything you can thoroughly, and with the best apparatus, but leave some of the original material for re-examination when improved methods of attack and analysis develop later.' Their work has resulted therefore in the preservation of continuity—so important in research. I may add that, to this day, this is the ruling idea of all the workers in Rothamsted. Lawes and Gilbert became world-famous ; they were honoured by Queen Victoria, Lawes was made a Baronet, and Gilbert a Knight, at a time, mind you, when such honours were rarely bestowed on men of science.

When their work was over, one phase of the history of our subject was passed. Specialization was already coming in, and this brought with it advantages and also dangers. It is inevitable that the development of a subject should lead to specialization but this tends to divide a science into water-tight compartments, with a corresponding lack of co-operation between the different specialists. It is obvious for example, that no one man can become an authority in all the branches of Entomology. But, as it takes years to achieve authority in any given subsection of a science, some form of specialization on the part of scientists is inevitable, if progress is to be rapid. Specialization was also accelerated by the great War, when it became necessary to explore every avenue of science in the attempt to increase our food supply.

A point of interest to be noted is, that up to the end of the Lawes and Gilbert era, chemistry was predominant in agricultural science.

But other sciences were being pressed into service. Plant-breeding was perhaps the next in historic order. The rediscovery of Mendel's Law opened up a new vista, and two striking examples can be given. One was the simple selection method, leading to the creation of *Marquis* wheat in Canada by Saunders and his father. Their aim was to obtain a good quality wheat producing a strong flour and they tested their wheats by chewing a few grains until the starch was removed, and then estimating the quality of the glutinous residue on which the strength of the flour depends. This was a simple but laborious method, for many hundreds of samples had to be examined. Another example is that of Biffen in England who, working on genetical lines was able to produce a good English wheat giving a strong flour, in contrast to the great majority of English varieties, whose flour is weak.

Animal-breeding was the next branch of agricultural science to develop, although historically it goes back a long way to the days of Bakewell of the 18th century—who made some remarkable improvements in cattle. This branch of agricultural science has made rapid strides, so much so, that sheep which formerly had to be reared for four or five years to make them fit for the market, hardly pass a summer through now. Again cattle which formerly required quite a number of years to grow to size for the butcher, are now brought to condition to produce 'baby' beef in under a year.

Then, recently there has been the development of soil microbiology which is now studied in great detail. This branch of science is associated especially with Sir John Russell, the present Director of Rothamsted.

I should like to remind you, however, that these developments I have just mentioned were foreshadowed by Lawes and Gilbert, and Warington (an associate of theirs), for as I have already told you, they ranged over the whole field of agricultural science.

At the present day there is hardly a science that is not directly applicable to agriculture. Physics—which had been worked at tentatively by Schubler—and which was thrown into the background by the chemical achievements of Lawes and Gilbert—is now coming into its own again, and much work in this branch has been recently done in America and England. Mathematics has come to be recognized as an important science in agriculture and is particularly of value to economic biologists in the design and in the interpretation of experiments; statistics has in fact removed the elements of uncertainty in our field experiments and has given us a definite knowledge of the degree of reliability. Branches of chemistry, biological sciences, mycology and entomology have all entered the field of agricultural research until practically no pure science has been left out.

The question therefore arises how we can most usefully employ these sciences for the advancement of agriculture—whether we, its practitioners and consultants, should be primarily agriculturists or pure scientists. I think there are no two answers to that: I share the general opinion that an agricultural scientist should be primarily a research worker of proved merit in some pure science, who has turned his attention to agriculture, rather than a trained agriculturist who has turned his attention to agricultural science. For, in the latter case, the man, (unless he is a genius and therefore, bound by no generalizations) cannot envisage the real nature of the scientific problems he is endeavouring to solve.

I will now put before you a number of lines of investigation along which I believe, will lie the immediate future development of agricultural science. There is the prevention and control of diseases of animals and plants; this is the outstanding problem for mycologists, entomologists and pathologists. A reputation is awaiting a worker or a team of workers, who will unravel the problem of virus disease which is now baffling the whole world of science. The indications are, however, that the solution will not be arrived at in one stroke, but will be secured by a gradual working up of small advances made by different workers and in different places. The amount of money lost to agriculturists by diseases in India and England is impossible to estimate—probably it will run to crores of rupees and millions of pounds; and so, work on this branch is going to pay for itself many times over.

Secondly, plant physiological studies, particularly of the extensive material used in plant-breeding work, will provide the clue for unravelling many difficulties now facing the plant-breeder. I have great hopes of this branch of work, for there is still great scope for plant-breeding studies in this country.

Thirdly, the bio-chemistry of what we mean by *quality* in agricultural produce, will receive great attention. Work on this is already being done in England, and in this connection I may mention the production of barley for malt. Malting involves traditional knowledge, and quality is tested by empirical methods based on previous experience. Biochemical studies are now providing a scientific explanation of these empirical tests; in particular the amount and composition of the various nitrogenous compounds in the barley grain has been examined and relationships have been found between these and certain other barley grains, characters on which the maltster relies for his estimate of quality. I need hardly point out to this audience that the nutritive value of various agricultural products whether for humans or animals is essentially a bio-chemical problem.

Fourthly, there is a line of work familiar to you in Coimbatore, namely, the base exchange phenomena in soils. In spite of the vast amount of work done so far on the chemical analysis of soils, the bearing of the results on the inherent fertility of the soil was only qualitative. But recently base exchange studies founded on modern physico-chemical theories of replaceable ions and the nature of the soil particle surface have resulted in new analytical methods which have vastly improved our measurements of soil fertility. This problem, therefore, is of considerable economic importance, and it will help the analyst to give the farmer advice on the kind and quantity of manure to be applied. This branch of study is a line of work where two types of scientists, physicists and chemists are able to co-operate to their mutual benefit.

Fifthly, soil physics (started so early by Schubler) is now ripe for further research and advances. Soil moisture, the determination of the effects of irrigation, the implements for promoting tilth, are all studies repaying attention. India has already won fame in the realm of pure physics research through the work of Professor Sir C. V. Raman and others, and I see no reason why her younger physicists should not make great advances in soil physics.

Sixthly, the new conception of soil classification will receive increasing attention. This work started in Russia, and has already been adopted in America, but so far little concerted attention has been given to it in the British Empire. It was started as an academic pursuit without reference to any possible direct useful end. The Russian studies showed that the tpye of mature soil which developed in any given area was very largely decided by the climate of that area. In fact, the climate zones and the soil zones practically coincided. In America, the original soil surveys based on mechanical and chemical analyses were revised during the past 2 or 3 years in conformity with Russian method, and they have shown that soil characteristics are explained more by this survey, than by the old laboratory methods. It is often said that this kind of survey is unnecessary in long settled countries such as India. Even if this were true—and I do not subscribe to the statement—a survey is of great value to agricultural scientists. To give only one example, the plant-breeder's problem is made more precise if he knows the soil types of the areas for which he is breeding fresh varieties. The new Imperial Bureau of Soil Science at Rothamsted is attempting to co-ordinate soil survey work in the Empire, with the object of drawing up a soil survey map of the British Empire. The ultimate result of surveys in all countries will be that the whole world will be divided into unified systems of soil zones, universally understood—and recognized and it will be a most striking unification indeed. In agricultural science—as in other sciences unification is desirable. All nations are members in the brotherhood of scientists and in the search for truth; among scientists at any rate, there are no barriers between one country and another.